Analysis of Results from ASIAEX East China Sea: Acoustic Interaction with the Sea Surface

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LONG-TERM GOALS

To develop physics-based, predictive sonar models for mid- to high-frequency acoustic scattering and reflection from the air-sea interface. The models are governed by wind speed, parameterizations of the sea surface wave spectrum, and near-surface bubble population.

OBJECTIVES

Analyze and model sea surface scattering and reflection measurements made during the Asian Seas International Acoustics Experiment (ASIAEX) conducted in the East China Sea (May-June 2001). The primary acoustic data set studied this year consists of measurements of vertical coherence for single and multiple-interaction forward scattering from the sea surface, made simultaneous with measurements of the sea surface directional wave spectrum, and other measurements of the air-sea interface.

APPROACH

The van Cittert-Zernike theorem relates the spatial correlation across an array, to the distribution of incoherent intensity on the radiating surface that the array has sensed (for astronomical geometries this relation is via Fourier transform). We have applied the van Cittert-Zernike theorem to ASIAEX measurements of spatial coherence by assuming that the ensonified sea surface becomes in effect an incoherently radiating surface. The advantage of this approach is that it can be used to study propagation of spatial coherence and the spatial coherence in paths that have undergone multiple interactions with the sea surface.

WORK COMPLETED

ASIAEX East China Sea project coordination: The final ASIAEX meeting was held in Chengdu, China in October 2002 [1], wherein plans for a special issue of the IEEE *Journal of Oceanic Engineering* on Asian Marginal Seas were outlined. Since this meeting, the PI has served as special issue Guest Editor for the approximately 15 manuscripts on the subject of ASIAEX East China Sea submitted thus far.

Data analysis and reporting: The paper, "Forward Scattering from the Sea Surface and the van Cittert-Zernike Theorem" was submitted in May and accepted to the *J. Acoust. Soc. Am.* [2]. The PI

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14. ABSTRACT
To develop physics-based, predictive sonar models for mid- to high-frequency acoustic scattering and reflection from the air-sea interface. The models are governed by wind speed, parameterizations of the sea surface wave spectrum, and near-surface bubble population.

15. SUBJECT TERMS

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has also been involved in the works [3-6] concerning various experimental aspects of ASIAEX East China Sea.

RESULTS

Underwater acoustic field measurement results from ASIAEX are diagrammed in Fig. 1. The complex spatial coherence of a sound field forward scattered from the sea surface was measured using a vertical line array (VLA), separated from the source by 500 m.

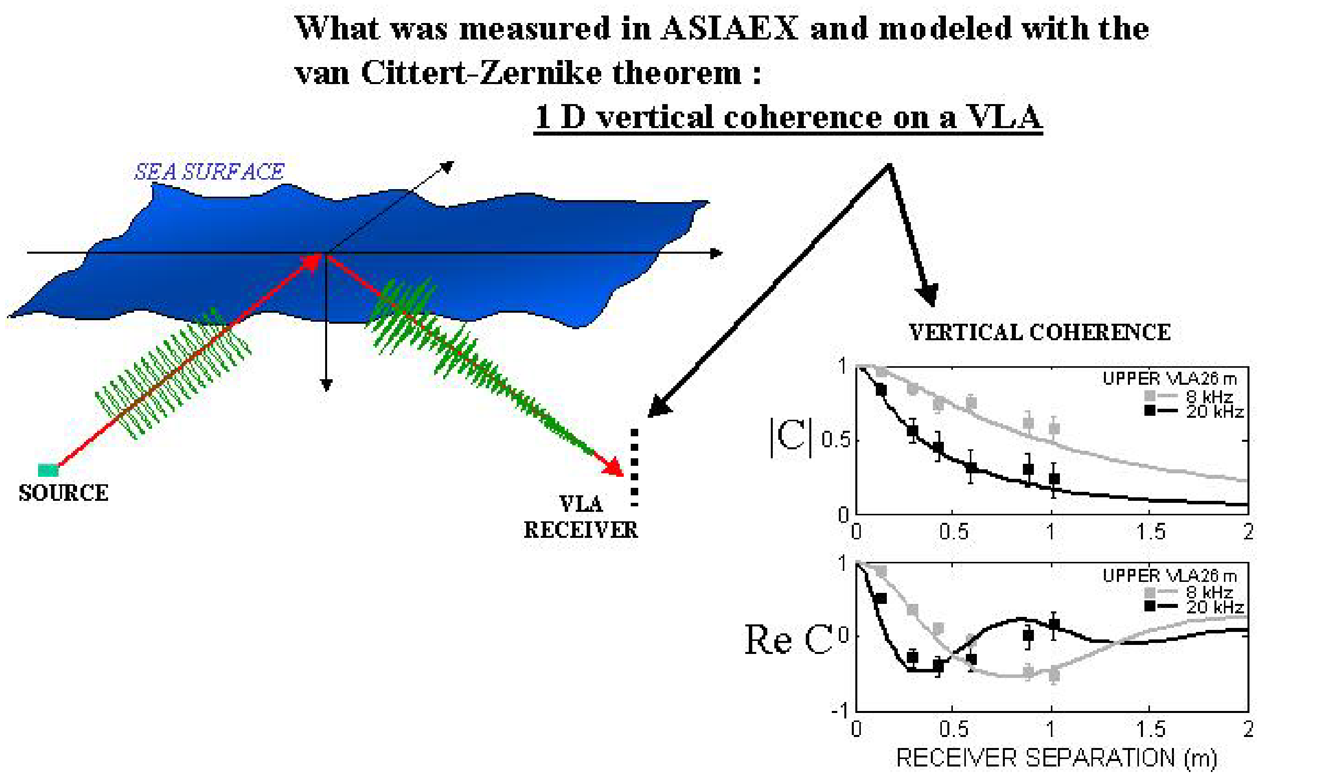

Figure 1. Upper left: Sketch of sound pulse emitted from source being forward-scattered from the sea surface with time-distorted version received on a vertical line array (VLA) at range 500 m. Lower right: Estimates of spatial coherence (symbols) compared to equivalent model (lines) generated by the van Cittert-Zernike theorem. Spatial coherence is expressed in terms of magnitude (upper plot) and real part (lower plot) as a function of receiver separation on the VLA. Data and models for 8 kHz sound (gray color) and 20 kHz sound (black color) are shown.

Figure 2 summarizes how model curves for vertical spatial coherence are generated. The process starts with analysis of the sea surface directional wave spectrum (I) measured concurrently with the acoustic measurements, which is used to estimate the bistatatic cross section (II) following procedure in [2]. Estimating spatial coherence (III) from the bistatic cross section is achieved via the van Cittert-Zernike theorem as outlined in [2].

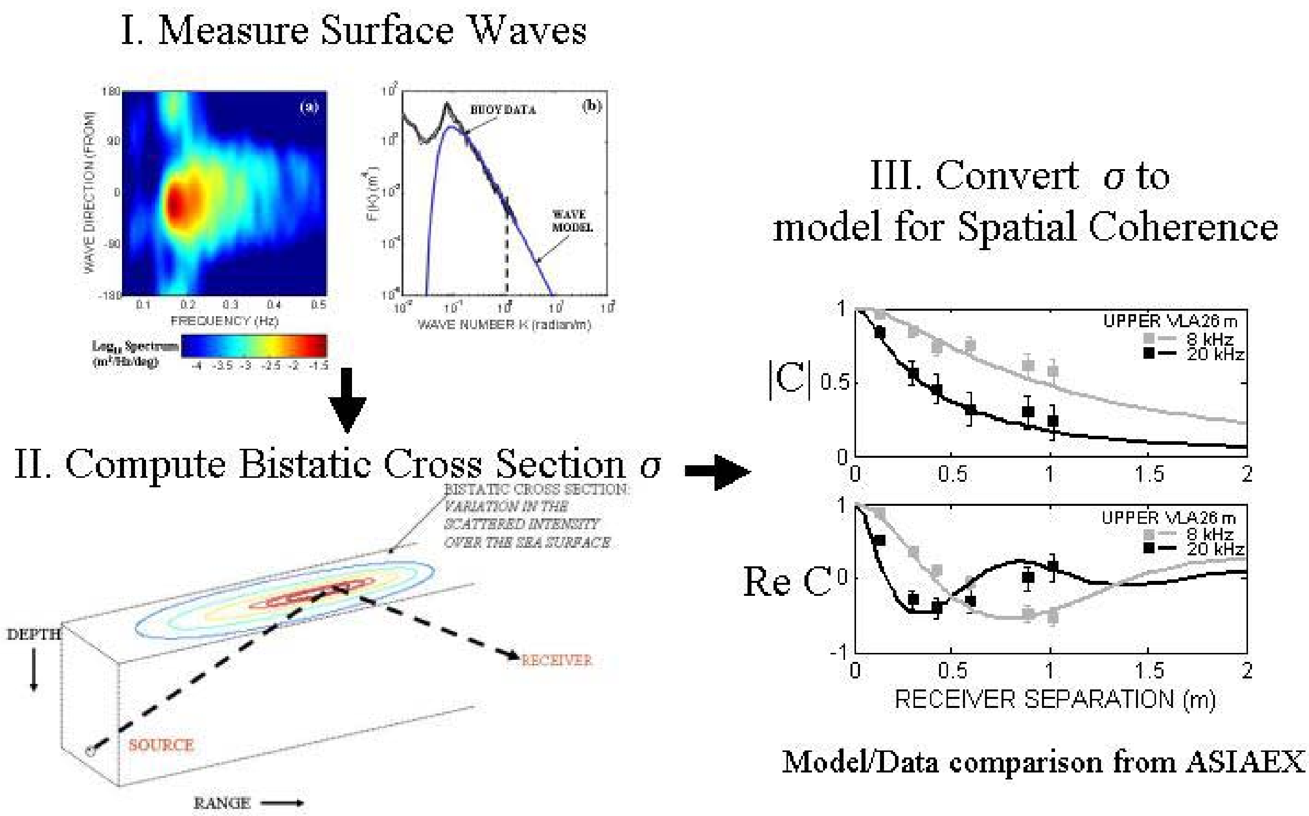

***Figure 2**. How model curves for vertical spatial coherence are generated: (I) field measurements of the directional wave spectrum are used to estimate the bistatic cross section (II), spatial coherence (III) is derived from the bistatic cross section via the van Cittert-Zernike theorem.*

In summary, the most significant results pertain to extending the van Cittert Zernike formalism to underwater acoustic geometries, and confirming theoretical results with measurements made during ASIAEX.

These results lend themselves to new capabilities in underwater acoustic imaging and communication, some of which will be evaluated this next year.

IMPACT/APPLICATIONS

With naval operations becoming ever more littoral oriented, the sea surface becomes increasingly important in setting the performance bounds for naval sonar systems.

Our studies on forward scattering from the sea surface in the East China Sea have direct application to models for sonar detection, communication, and imaging, utilizing the sea surface bounce path. At present, the primary application involves long-range Synthetic Aperture Sonar (SAS), for which our results on spatial coherence in forward scattering from the sea surface (both data and modeling) are

being used to establish a potential performance envelope, and are being utilized in SAS development work at CSS and Dynamics Technology.

RELATED PROJECTS

This research is integrated together with several projects within the ASIAEX field program (James Miller (URI), D. J. Tang (APL-UW), Jixun Zhou (Georgia Institute of Tech), and Zhaohui Peng (Institute of Acoustics, Beijing), with focus on propagation, and surface scattering and reflection, bottom reflection, and volume scattering effects in the East China Sea.

The PI is also working on a transition project "Simulating SAS Imaging via Surface Bounce Paths" (ONR 32CM). This project utilizes ASIAEX spatial coherence measurements, and the modeling techniques derived here.

PUBLICATIONS

[1] Dajun Tang, S. R. Ramp, P. H. Dahl, James Lynch, Jixun Zhou, Renhe Zhang, Ching-Sang Chiu, R.C. Spindel, and J. Simmen, Proceedings, The Asian Seas International Acoustics Experiment (ASIAEX) International Symposium, Chengdu, China, October 14-18, 2002, APL-UW TR 0201, December 2002. [published]

[2] Dahl, P. H., "Forward Scattering from the Sea Surface and the van Cittert-Zernike Theorem", *J. Acoust. Soc. Am.* [in press, refereed]

[3] Zhaohui Peng, Ji-xun Zhou, Peter H. Dahl, and Renhe Zhang, "Seabottom acoustic parameters from dispersion analysis and transmission loss in the East China Sea", *IEEE J . Oceanic Eng.* [submitted, refereed]

[4] Jeewoong Choi and Peter H. Dahl, "Mid to High Frequency Bottom Loss in the East China Sea", *IEEE J . Oceanic Eng.* [submitted, refereed]

[5] Ji-Xun Zhou, Xue-Zhen Zhang, Peter H. Rogers, Jeffery A. Simmen, Peter H. Dahl,Guoliang Jin and Zhaohui Peng, Reverberation Vertical Coherence and Seabottom Geoacoustic Inversion in Shallow Water *IEEE J . Oceanic Eng.* [submitted, refereed]

[6] S. R. Ramp, J. F. Lynch, P. H. Dahl,
C-S. Chiu, and J. A. Simmen, "Program Fosters Advances in Shallow-water Acoustics in Southeastern Asia", *EOS Transactions American Physical Society*, Vol. 84, No. 37, September 2003. [published, refereed]

HONORS/AWARDS/PRIZES

Name and Institution:	Peter H. Dahl, Applied Physics Laboratory, University of Washington
Award:	Fellow, Acoustical Society of America